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Y-factor attenuator
signal-to-noise power factor
signal-to-noise ratio

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The receiver noise factor (noise figure) is the ratio of input signal-to-noise power ratio at the antenna terminals to the signal-to-noise power ratio at the output terminals of the receiver, when the input termination is at room temperature (290°K). The average noise factor over the frequency range of interest for the particular case of AM and FM surveillance receivers is a measure of the amount of noise power added to a signal by the receiver, thereby degrading signal quality. The noise factor is usually expressed in decibels, it is

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Item 20 Continued

commonly referred to as the noise figure, F(db) = 10 log F. The average noise factor $F = P_{si}/P_{ni} \times P_{no}/P_{so}$ where P_{si} is the signal power input, P_{ni} is the noise power input, P_{no} is the noise power output and P_{so} is the signal power output. Five methods of measurement are given, and the method used will depend upon the test equipment available, the desired accuracy, and the time available to devote to the measurement. Noise figure is usually measured only for the linear parts of the receiver that precede the demodulator. For CW and AM receivers, this includes the RF and IF stages up to the second detector. For FM receivers, this includes the RF and IF stages up to the first limiter stage. For receivers with a linear demodulator, such as a product detector, noise figure may be measured for the entire receiver from the antenna input terminals to the audio output terminals. Reference report: NBSIR 73-333, M. G. Arthur, October 1973.

US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-105 2 February 1983
Test Operations Procedure 6-2-594
AD No.

1.0 SCOPE. The receiver noise factor (noise figure) is the ratio of input signal-to-noise power ratio at the antenna terminals to the signal-to-noise power ratio at the output terminals of the receiver, when the input termination is at room temperature (290°K). The average noise factor over the frequency range of interest for the particular case of AM and FM surveillance receivers is a measure of the amount of noise power added to a signal by the receiver, thereby degrading signal quality. The noise factor is usually expressed in decibels, it is commonly referred to as the noise figure, $F(db) = 10 \log F$. The average noise factor $F = P_{si}/P_{ni} \times P_{no}/P_{so}$ where P_{si} is the signal power input, P_{ni} is the noise power input, P_{no} is the noise power output and P_{so} is the signal power output.

Five methods of measurement are given, and the method used will depend upon the test equipment available, the desired accuracy, and the time available to devote to the measurement*. Noise figure is usually measured only for the linear parts of the receiver that precede the demodulator. For CW and AM receivers, this includes the RF and IF stages up to the second detector. For FM receivers, this includes the RF and IF stages up to the first limiter stage. For receivers with a linear demodulator, such as a product detector, noise figure may be measured for the entire receiver from the antenna input terminals to the audio output terminals.

2.0 FACILITIES AND INSTRUMENTATION. The test item shall be placed in operating condition as outlined in the equipment technical manual.

2.1 Facilities. A communications test facility complete with benches equipped with basic ac power outlets, dc power supplies, and appropriate terminals, leads, and connectors as required. The facility shall have access to an equipment pool and a shielded enclosure.

*This TOP has been taken from the Test Procedures Handbook for Surveillance Receivers, NBSIR 73-333, October 1973 by M. G. Arthur. It was prepared for the US Army by the EM Field Division, NBS, Boulder, CO 80302.

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Item/Characteristics	Tolerance
Shielded Enclosure 100 or 200 dB as required	-5 dB, + ∞
Power Line Filter	-5 dB, + ∞
Line voltage	$\pm$5 percent of nominal rms volts

2.2 Instrumentation. Must have a current calibration certificate. The generators shall either have at least 40 dB harmonic suppression or be backed by a tunable filter.

	Item/Characteristics	Tolerance
1.	Automatic Noise Figure Meter (ANFM) HP 342A, AILTECH 75 PANFI or equivalent	$\pm$0.5 dB
2.	Broadband Noise Generator HP 346B or equivalent	$\pm$0.5 dB
3.	Input Impedance Matching Transformers	$\pm$0.5 dB of Z_g @ f_o
4.	Hot/Cold Standard Random Noise Generator AILTECH 7009 or equivalent	$\pm$0.1 PPM
5.	Power Meter HP 436A or equivalent	$\pm$0.5 dB
6.	Variable attenuator	$\pm$0.5 dB of requirement
7.	Signal Level Indicator (voltmeter, power meter, receiver, etc.)	
8.	Temperature - limited diode noise generator	0.3 to 1.5 dB
9.	3 dB fixed attenuator	

3.0 PREPARATION FOR TEST

3.1 Facilities. Assure facilities conform to minimum requirements.

3.2 Equipment. Testing is conducted in a normal conditioned environment with the usual ancillary equipment to include the isolation network.

3.3 Instrumentation. All instrumentation is to be set up in accordance with figure 1.

3.4 Characteristics Required (Technical). Record the following:

3.4.1 Test Item. Serial number and nomenclature. Other data if required by test plan.

3.4.2 Instrumentation. Name, type/model, serial number, and calibration due date of each.

3.4.3 Personnel Data. Technician(s)' name(s), MOS/series, and title(s).

4.0 TEST CONTROLS

4.1 Set up all measuring instrumentation and the test item in a screen room to minimize the effects of interfering signals, or in a field area having low measureable interference levels.

4.2 Make the following initial control settings as applicable on the receiver: Band switch, frequency tuning, and IF bandwidth as desired. Set the antenna trimmer to obtain a peak reading on the receiver's signal strength meter (if provided) or peak audio output; the IF gain as required, RF gain to maximum for the test in progress. Set the beat frequency oscillator, and the noise limiter, to "off". Set the AGC/MGC mode switch to MGC. The above settings do not apply to digitally tuned receivers because they do not have these controls.

5.0 PERFORMANCE TESTS

5.1 Method - Automatic Noise Figure Meter. This method uses an automatic noise figure meter (ANFM), which includes a switched random noise generator, as shown in figure 1. The ANFM cyclically switches the noise generator between two output power levels, and automatically computes noise figure from the output signal of the receiver. The measured noise figure is displayed by the panel meter on the ANFM.

Measurement uncertainties as small as 0.3 dB are possible under best conditions, and range from approximately 0.5 dB to 1.5 dB under typical conditions. The method uses equipment that is commonly available for use above 30 MHz, limited availability between 10 and 30 MHz, but unavailable below 10 MHz. It is typically quick and convenient to perform, and is especially convenient when making adjustments to optimize receiver noise figure.

5.1.1 Test Equipment Required.

1. Automatic noise figure meter (ANFM) AILTECH 7514 Precision Automatic Noise Figure Indicator (PANFI), equal or better.

2. Noise generator for use with the ANFM AILTECH 7615, 7616, and 7617 (76 Series) Noise Generators, equal or better.

3. Input impedance matching transformer, as required.

5.1.2 Procedure.

1. Connect the input port of the receiver to the output port of the NOISE GENERATOR through an IMPEDANCE TRANSFORMER that provides the specified source impedance, Z_s, to the receiver at the measurement frequency, f_o. If the noise generator output impedance equals Z_s, no transformer is needed.

2. Connect the input port of the ANFM to the output of the last linear IF amplifier stage. Follow the instructions of the manufacturer of the ANFM to make this connection.

3. Set receiver controls as given in paragraph 4.2.

Note: For some receivers, maximum RF/IF gain may produce overloading either in the latter IF stages or in the amplifier of the ANFM. In this case, set the RF/IF gain to produce an input level to the ANFM that is from 3 dB to 10 dB greater than the minimum level required by the ANFM.

4. Tune the receiver to the measurement frequency, f_o.

5. Adjust the ANFM according to manufacturer's instructions. This usually includes a calibration adjustment, a mode selection, and selection of scale range.

6. Measure noise factor, F, in decibels, by following the procedure given by the manufacturer.

7. Correct the measured value of F as instructed by the manufacturer. Also correct the results for the effect of the impedance transformer, if used. This is the noise factor, in decibels, of the linear portions of the receiver RF/IF stages when tuned to frequency f_o.

5.1.3 Data Required.

1. Record the measurement frequency, f_o, in kilohertz or megahertz.

2. Record the value of source impedance, Z_s, in ohms, connected to the receiver input port.

3. Record the measured value of F, in decibels.

4. Record the corrections applied to the measured value of F. These include the following:

a. Noise generator termination temperature

b. VSWR

c. Impedance transformer loss

d. Cable loss

e. Image response

5.1.4 Measurement Errors.

The principal sources of measurement error are the following:

1. Uncertainty, ΔT_h, in the noise temperature, T_h, of the noise generator.

2. Uncertainty, ΔT_a, of the ambient temperature, T_a, of the generator termination.

3. Uncertainty, ΔF_z, in F due to the VSWR of the generator impedance.

4. Uncertainty, ΔF_i, in F due to image response.

5. Uncertainty, ΔF_c, in F due to the uncertainty in the ANFM calibration.

The total uncertainty, ΔF, in the measured value of F will vary according to the particular ANFM system used. Refer to the manufacturer's operating manual for the procedure for determining ΔF.

5.2 Method - Y-Factor/Power Meter.

This method uses a pair of random noise generators and a power meter as shown in figure 2. The hot and cold noise generators supply known input noise powers to the receiver in a band of frequencies which includes that to which the receiver is tuned. The power meter measures the power levels from the last linear IF stage. The ratio of the two power levels corresponding to the two input power levels is the Y-factor. Noise factor is computed from the measured Y-factor and the known power levels of the two generators.

Measurement uncertainties as small as 0.2 dB are possible under best conditions, and range from approximately 0.3 dB to 1 dB under typical conditions. The method uses sophisticated equipment, but it is commonly available.

5.2.1 Test Equipment Required.

1. Hot random noise generator AILTECH Hot/Cold Standard P/N 7009, or equal (boiling water 373K terminal)

2. Cold random noise generator AILTECH Hot/Cold Standard P/N 7009, or equal (in liquid nitrogen 77.3K terminal)

3. Input impedance matching transformer

4. Power meter

5.2.2 Procedure.

1. Connect the input port of the receiver to the output port of the HOT NOISE GENERATOR through an IMPEDANCE TRANSFORMER that provides the specified source impedance, Z_s, to the receiver at the measurement frequency, f_o. If the noise generator output impedance equals Z_s, no transformer is needed.

2. Connect the input port of the POWER METER to the output of the last linear IF amplifier stage.

3. Set receiver controls as given in paragraph 4.2, page 3.

Note: For some receivers, maximum RF/IF gain may produce overloading in the latter IF stages. In this case, set the controls to produce maximum RF gain without overload anywhere in the measurement system.

4. Tune the receiver to the measurement frequency, f_o.

5. Measure the output power, P_h, from the last linear IF amplifier stage.

6. Disconnect the hot noise generator and connect the COLD NOISE GENERATOR in its place.

7. Measure the output power, P_c, from the last linear IF amplifier stage.

8. Calculate the Y-factor from the equation

$$Y = \frac{P_h}{P_c}$$

9. Calculate the noise factor from the equation

$$F = \frac{T_h - YT_c}{290\ (Y-1)} + 1 = \frac{(373/290 - Y77.3/290)}{Y-1} + 1$$

and

$$F\ (\text{dB}) = 10 \log F = 10 \log \frac{0.73345Y + 0.2862}{Y-1}$$

This is the noise factor, in decibels, of the linear portions of the receiver RF/IF stages when tuned to frequency f_o.

5.2.3 Data Required.

1. Record the measurement frequency, f_o, in kilohertz or megahertz.

2. Record the value of source impedance, Z_s, in ohms, connected to the receiver input port.

3. Record the noise temperature, T_h, in kelvins, of the hot noise generator.

4. Record the noise temperature, T_c, in kelvins, of the cold noise generator.

5. Record the output power, P_h, in milliwatts.

6. Record the output power, P_c, in milliwatts.

7. Record the calculated Y-factor, Y.

8. Record the calculated value of noise factor, F, in decibels.

5.2.4 Measurement Errors.

The principal sources of measurement error are the following:

1. Uncertainty, ΔT_h, in the noise temperature, T_h of the hot noise generator.

2. Uncertainty, ΔT_c, in the noise temperature, T_c of the cold noise generator.

3. Uncertainty, ΔP_h, in the measured value of P_h.

4. Uncertainty, ΔP_c, in the measured value of P_c.

The total uncertainty, ΔF, in the calculated value of F is given by the equation

$$\Delta F = C_1 \Delta T_h + C_2 \Delta T_c + C_3 \Delta Y.$$

The uncertainty coefficients C_1, C_2, and C_3 are given by the equations

$$C_1 = \frac{1}{290\ (Y-1)}, \quad C_2 = \frac{-Y}{290\ (Y-1)}, \quad C_3 = \frac{T_c - T_h}{290\ (Y-1)^2}.$$

The uncertainties ΔT_h and ΔT_c are obtained from the manufacturer's specifications or from the results of calibrating T_h and T_c. Uncertainty ΔY is given by the relation

$$\Delta Y = \Delta P_h + \Delta P_c,$$

where ΔP_h and ΔP_c are obtained from the manufacturer's specifications on the power meter.

The relative measurement uncertainty, ΔF(dB), expressed in decibels, is given approximately, for small uncertainties, by the equation

$$\Delta F\ (\mathrm{dB}) = 10 \log\left(1 + \frac{\Delta F}{F}\right)$$

5.3 Method - Y-Factor/Attenuator.

This method uses a pair of random noise generators and a variable attenuator as shown in figure 3. The hot and cold noise generators supply known input powers to the receiver in a band of frequencies which includes that to which the receiver is tuned. The attenuator measures the ratio of the two receiver output power levels corresponding to the two input power levels from the generators. Noise factors is computed from the measured power ratio and the known generators power levels.

Measurement uncertainties as small as 0.2 dB are possible under best conditions, and range from approximately 0.3 dB to 1 dB under typical conditions. The method uses sophisticated equipment, but it is commonly available.

5.3.1 Test Equipment Required.

1. Hot random noise generator (see 5.2.1)

2. Cold random noise generator

3. Input impedance matching transformer

4. Variable attenuator (AILTECH 32-series, or equal)

5. Signal level indicator (voltmeter, power meter, receiver, etc.)

5.3.2 Procedure.

1. Connect the input port of the receiver to the output port of the COLD NOISE GENERATOR through an IMPEDANCE TRANSFORMER that provides the specified source impedance, Z_s, to the receiver at the measurement frequency, f_o. If the noise generator output impedance equals Z_s, no transformer is needed.

2. Connect the SIGNAL LEVEL INDICATOR to the output of the last linear IF amplifier stage through the VARIABLE ATTENUATOR.

3. Set receiver controls as given in paragraph 4.2, page 3.

Note: For some receivers, maximum RF/IF gain may produce overloading in the latter IF stages. In this case, set the controls to produce maximum RF gain without overload anywhere in the measurement system.

4. Tune the receiver to the measurement frequency, f_o.

5. Adjust the attenuator and the sensitivity of the signal level indicator to produce a convenient indicator reading near full scale.

6. Record the indicator reading, I_c.

7. Record the attenuator setting, A_c(dB), in decibels.

8. Disconnect the cold noise generator and connect the HOT NOISE GENERATOR in its place.

9. Adjust the attenuator to produce the indicator reading, I_c.

10. Record the new attenuator setting, A_h (dB), in decibels.

11. Compute the Y-factor in decibels from the equation

$$Y(dB) = A_c(dB) - A_h(dB).$$

12. Convert the Y-factor in decibels to Y-factor by the equation

$$Y = \text{antilog}\ \frac{Y(dB)}{10}.$$

13. Calculate the noise factor from the equation

$$F = \frac{T_h - YT_c}{290\ (Y-1)} + 1,$$

and

$$F(dB) = 10 \log F.$$

This is the noise factor, in decibels, of the linear portions of the receiver RF/IF stages when tuned to frequency f_o.

5.3.3 Data Required.

1. Record the measurement frequency, f_o, in kilohertz or megahertz.

2. Record the value of source impedance, Z_s, in ohms, connected to the receiver input port.

3. Record the noise temperature, T_h, in kelvins, of the hot noise generator.

4. Record the noise temperature, T_c, in kelvins, of the cold noise generator.

5. Record the indicator reading, I_c, in millivolts or milliwatts.

6. Record the attenuator setting, A_c (dB), in decibels.

7. Record the attenuator setting, A_h (dB), in decibels.

8. Record the Y-factor, Y(dB), in decibels.

9. Record the numeric Y-factor, Y.

10. Record the calculated value of noise factor, F, in decibels.

5.3.4 Measurement Errors.

The principal sources of measurement error are the following:

1. Uncertainty, ΔT_h, in the noise temperature, T_h, of the hot noise generator.

2. Uncertainty, ΔT_c, in the noise temperature, T_c, of the cold noise generator.

3. Uncertainty, ΔA_c, in the measured value of A_c (dB).

4. Uncertainty, ΔA_h, in the measured value of A_h (dB).

The total uncertainty, ΔF, in the calculated value of F is given by the equation

$$\Delta F = C_1 \Delta T_h + C_2 \Delta T_c + C_3 \Delta Y.$$

The uncertainty coefficients C_1, C_2, and C_3 are given by the equations

$$C_1 = \frac{1}{290\ (Y-1)}, \quad C_2 = \frac{-Y}{290\ (Y-1)}, \quad C_3 = \frac{T_c - T_h}{290\ (Y-1)^2}.$$

The uncertainties ΔT_h and ΔT_c are obtained from the manufacturer's specifications or from the results of calibrating T_h and T_c. Uncertainty ΔY is given by the relation

$$\Delta Y = \text{antilog} \frac{\Delta A_c\ (\text{dB}) + \Delta A_h\ (\text{dB})}{10},$$

here ΔA_c and ΔA_h are obtained from the manufacturer's specifications on the variable attenuator.

The relative measurement uncertainty, F(dB), expressed in decibels, is given approximately, for small uncertainties, by the equation

$$\Delta F \text{ (dB)} = 10 \log \left(1 + \frac{\Delta F}{F}\right)$$

5.4 Method - 3 dB.

This method uses a temperature-limited diode (TLD) noise generator and a 3 dB attenuator (hence its name) as shown in figure 4. The TLD noise generator supplies a known but adjustable input power to the receiver in a band of frequencies which includes that to which the receiver is tuned. The signal level indicator is used to indicate a reference level of output power.

With the noise generator output level adjusted to zero, and with the 3 dB attenuator out of the system, the receiver output power produces an indication on the signal level indicator. Then the 3 dB attenuator is inserted in the system, and the noise generator output is increased until the same indicator reading is obtained. Noise factor is read directly from the calibrated meter on the TLD noise generator.

Measurement uncertainties as small as 0.3 dB are possible under best conditions, and range from approximately 0.5 dB to 1.5 dB under typical conditions. The method uses commonly available test equipment, and is quick and convenient to perform.

5.4.1 Test Equipment Required.

1. Temperature-limited diode noise generator. A known noise-source NBS standard.

2. Input impedance matching transformer.

3. 3 dB fixed attenuator (AILTECH 32-series or equal).

4. Signal level indicator (voltmeter, power meter, receiver, etc.).

5.4.2 Procedure.

1. Connect the input port of the receiver to the output of the NOISE GENERATOR through an IMPEDANCE TRANSFORMER that provides the specified source impedance, Z_s, to the receiver at the measurement frequency, f_o. If the noise generator output impedance equals Z_s, no transformer is needed.

2. Connect the input port of the SIGNAL LEVEL INDICATOR to the output of the last linear IF amplifier stage.

3. Set receiver controls as given in paragraph 4.2, page 3.

Note: For some receivers, maximum RF/IF gain may produce overloading in the latter IF stages. In this case, set the controls to produce maximum RF gain without overload anywhere in the measurement system.

4. Tune the receiver to the measurement frequency, f_o.

5. Turn the emission current of the TLD noise generator to zero (leave the generator connected to the measurement system).

6. Adjust the sensitivity of the signal level indicator to produce a reading near full scale.

7. Record the indicator reading, I.

8. Disconnect the receiver from the signal level indicator.

9. Insert the 3 dB ATTENUATOR between the receiver and the signal level indicator.

Note: Make certain that the attenuator terminating impedances are proper so that 3 dB of attenuation is obtained.

10. Increase the emission current of the TLD noise generator to produce the indicator reading, I.

11. Record the indicated value of noise factor in decibels as read from the emission current meter on the TLD noise generator.

12. Apply a frequency correction to the indicated value of F(dB), if necessary as described in the manufacturer's operating manual, to provide a corrected value of F(dB). Also, correct F(dB) for the effect of ambient temperature within the noise generator as instructed by the manufacturer. This is the noise factor, in decibels, of the linear portions of the receiver RF stages when tuned to frequency f_o.

5.4.3 Data Required.

1. Record the measurement frequency, f_o, in kilohertz or megahertz.

2. Record the value of source impedance, Z_s, in ohms, connected to the receiver input port.

3. Record the indicator reading, I, in millovolts or milliwatts.

4. Record the indicated value of noise factor, F(dB), in decibels.

5. Record the frequency-corrected and temperature-corrected value of noise factor, F(dB), in decibels.

5.4.4 Measurement Errors.

The principal source of measurement error is the calibration of the TLD noise generator meter. The uncertainty, F(dB), in decibels in the measured value of F will vary according to the particular noise generator used. Refer to the manufacturer's operating manual for the procedure for determining F.

5.5 Method - Accurate and Automatic Noise Figure Measurements HP AN 64-3.

This method uses a desk-top computer to automate measurements, process data, and account for many small effects that, in manual noise measurement systems are bothersome to correct. The total error from many small effects can become significant. Corrections for these effects is routine and simple and will replace old, seriously questioned, often postponed, manual routines. The computer also provides data in the form desired. It lists and plots results without tedious tabulation of data requiring correction charts and graphs. The IF frequency can be anywhere in the 10 MHz to 18 GHz range and the measurement bandwidth can be chosen to suit the application.

The method uses general purpose equipment likely to be useful on other tests, and other equipment can often be substituted for the suggested equipment. The uncertainty with this system, considering all effects, at most frequencies is only about ± 0.22 dB. The repeatability of noise figure measurements from one system to another is within ± 0.1 dB.

5.5.1 Test Equipment Required.

Noise Source HP 346B
Power Supply HP 6205B
Desk Top Computer HP 9825A
Plotter HP 9872A
Attenuator/Switch Driver HP 11713A
Programmable Step Attenuator HP 8496G
Power Sensor HP 8484A
Power Meter HP 436A
HP-IB cables, cards, and connectors
Unit under test (UUT)

5.5.2 Procedure.

Follow Part II, Assembly and Operation of HP Application, Note 64-3, June 1980.

Assemble, connect, and adjust controls as in figure 5 or figure 1-2 of AN 64-3.

Follow turn-on procedures on page 13 of AN 64-3.

Program software as described in AN 64-3.

5.5.3 Data Required.

Adjust the plotter so the pens P_1 and P_2 can move to the lower-left and upper-right corners. Plot the frequency scale along the bottom of the paper, the noise figure scale along the left edge and the gain scale along the right edge.

Program the appropriate parameters in accordance with instructions and listings in the HP Application Note 64-3, Chapters II and III.

5.5.4 Measurement Errors.

Repeat measurements with the plotter adjusted for the gain scale along the right edge. The repeated plots will show measurement errors in dB differences between plots.

Recommended changes to this publication should be forwarded to Commander, US Army Test and Evaluation Command, ATTN: DRSTE-AD-M, Aberdeen Proving Ground, MD, 21005. Technical information may be obtained from the preparing activity: Commander, US Army Electronic Proving Ground, ATTN: STEEP-MT-T, Ft Huachuca, AZ 85613. Additional copies are available from the Defense Technical Information Center, Cameron Station, Alexandria, VA 22314. This document is identified by the accession number (AD No.) printed on the first page.

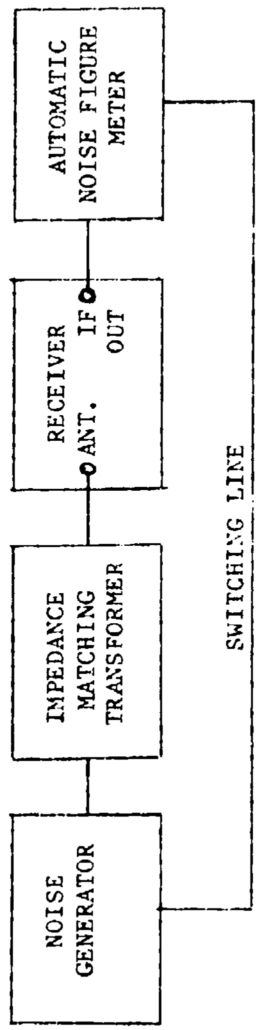

Figure 1. Test Set-up for Noise Factor, ANFM Method.

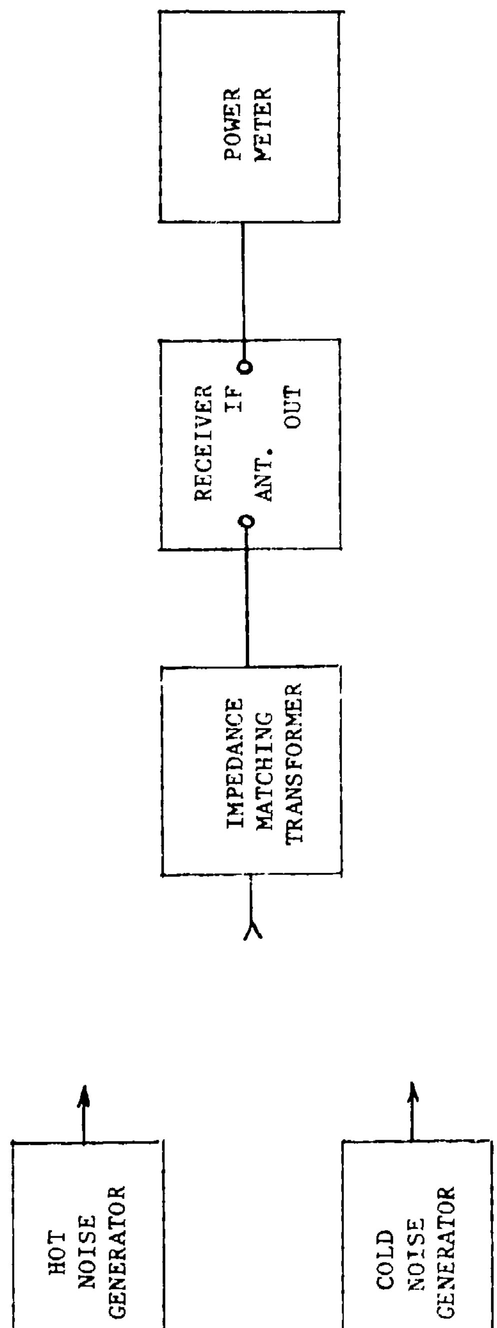

Figure 2. Test Set-up for Noise Factor, Y-Factor/Power Meter Method.

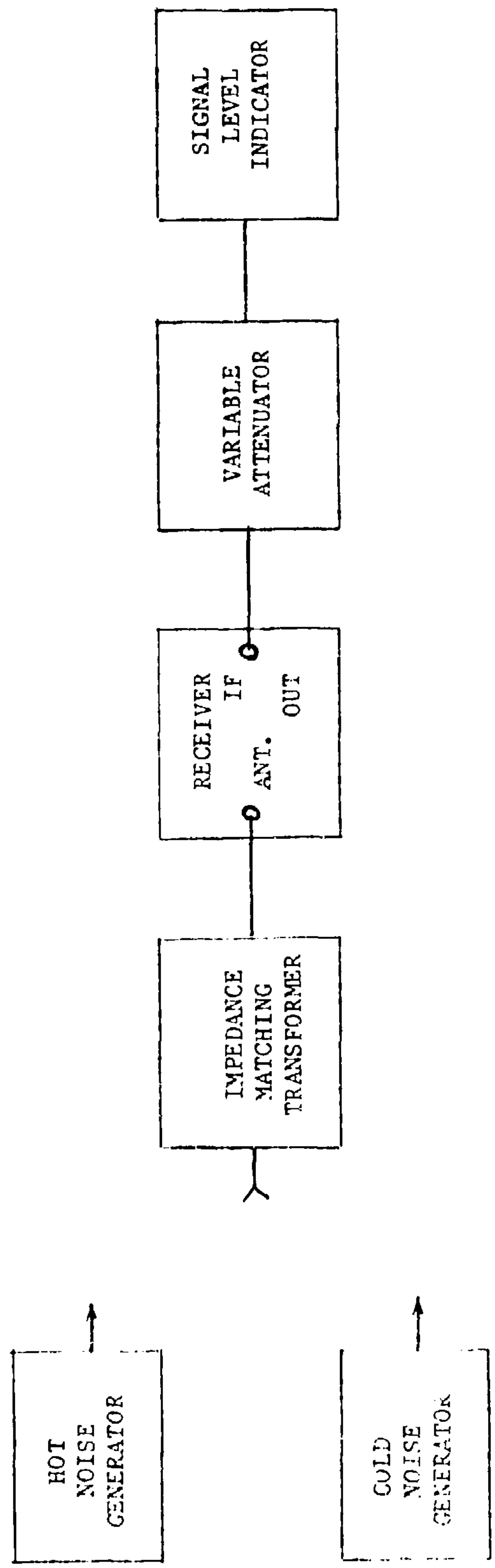

Figure 3. Test Set-up for Noise Factor, Y-Factor/Attenuator Method.

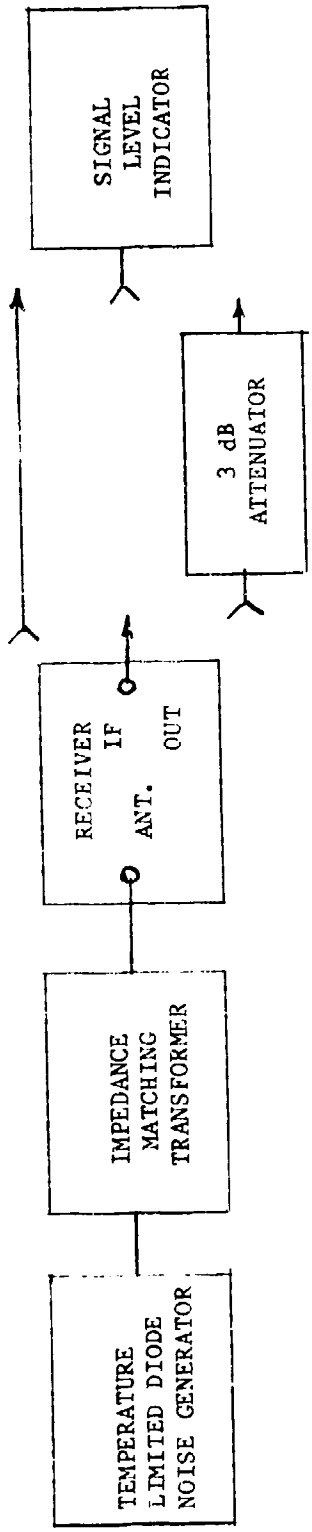

Figure 4. Test Set-up for Noise Factor, 3 dB Method.

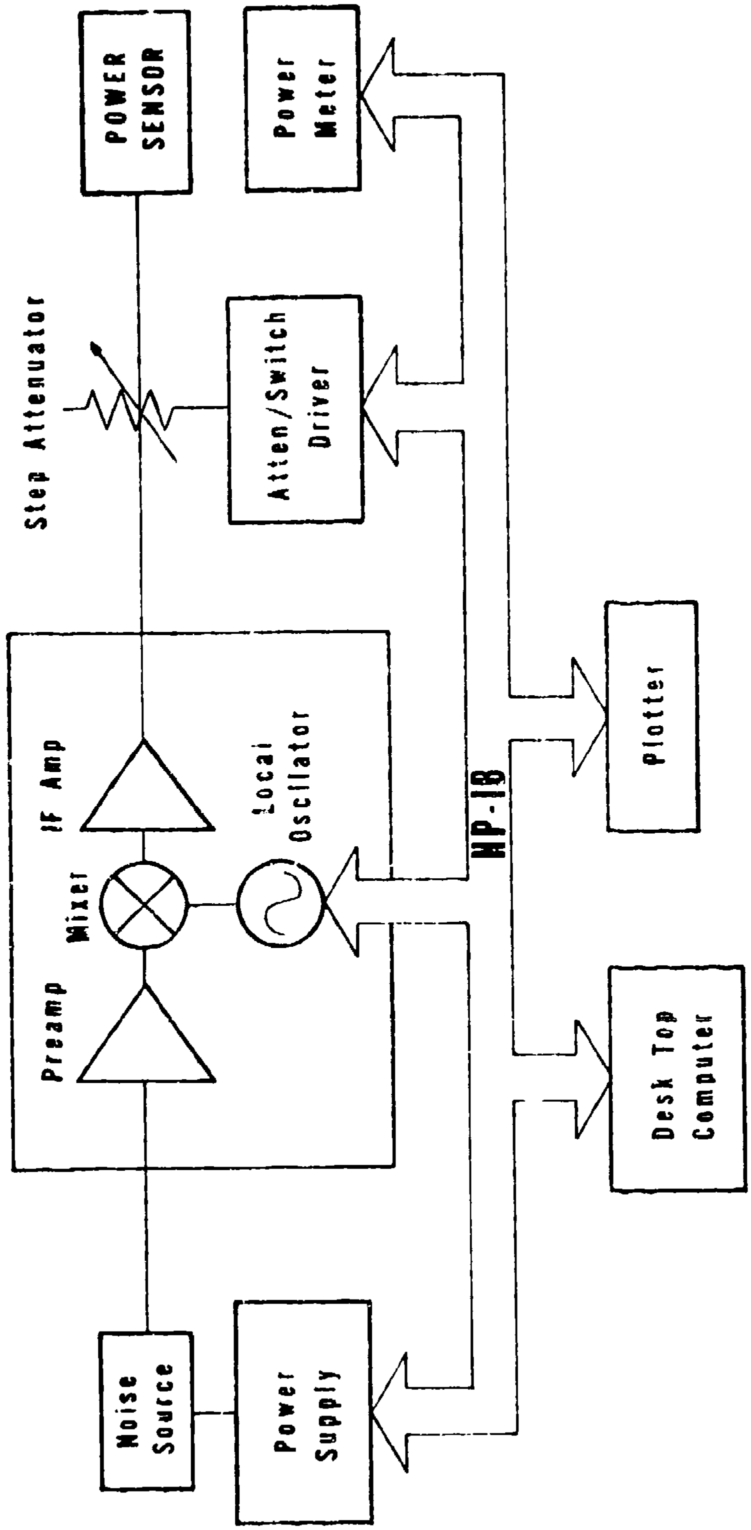

Figure 5. Automatic noise figure measurement system.

DATA SHEET FOR "AUTOMATIC NOISE FIGURE METER" METHOD

Record					Corrections		
f_o kHz or MHz	Z_s ohms	F(dB)	T_g term	VSWR	Z_t loss	Cable loss	Image Resp

DATA SHEET FOR "Y-FACTOR/POWER METER" METHOD

f_o kHz or MHz	Z_s ohms	T_h °Kelvin	T_c °Kelvin	P_h milliwatts	P_c milliwatts	Y Y-factor	F in dB

DATA SHEET FOR "Y-FACTOR/ATTENUATOR" METHOD

f_o kHz or MHz	Z_s ohms	T_h Kelvin	T_c Kelvin	I_c millivolts	A_c dB	A_h dB	Y_f dB	Y_f numeric	F_c dB

DATA SHEET FOR "3dB" METHOD

f_o kHz or MHz	Z_s ohms	I millivolts or milliwatts	F_i dB	F_{f-c} dB

APPENDIX B. REFERENCES

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